PB82-101676

Production Engineering and Marketing Analysis of the Rotating Disk Evaporator

Environmental Resources Management, Inc.
West Chester, PA

Prepared for

Municipal Environmental Research Lab.
Cincinnati, OH

Sep 81

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-600/2-81-179	ORD Report	PB82 101676

4. TITLE AND SUBTITLE	5. REPORT DATE
Production Engineering and Marketing Analysis of the Rotating Disk Evaporator	September 1981
	6. PERFORMING ORGANIZATION CODE U 249027

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Phillip L. Buckingham	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
Environmental Resources Management, Inc. 999 West Chester Pike West Chester, PA 19380	AZB1B
	11. CONTRACT/GRANT NO. 68-03-2738

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Municipal Environmental Research Laboratory - Cint.,OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, Ohio 45268	Final: 9/78 - 5/79
	14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES

Project Officer: Robert P. G. Bowker (513) 684-7620

16. ABSTRACT

Recent EPA-funded research into the on-site, mechanical evaporation of wastewater from single family homes revealed that a rotating disk evaporator (RDE) could function in a non-discharging mode. Such a device has potential use where site limitations preclude conventional methods for on-site disposal.

This report documents a marketing analysis made of the RDE. The marketing analysis defined the market potential for RDE systems, developed a practical design, estimated production and installation costs, and refined market estimates based on cost comparisons.

Total installed cost of an RDE system (including storage tank) was estimated to be in excess of $20,000 (1979). Because of the high cost, the potential RDE market is limited to very expensive homes, second homes with no winter occupancy, and high cash flow - low sewage flow commercial establishments. Furthermore, unfavorable climatic conditions eliminate much of the nation from consideration.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Sewage disposal Evaporation	On-site sewage disposal Non-sewered area	13B

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21.
Release to Public	unclassified	
	20. SECURITY CLASS (This page) unclassified	22. PRICE

EPA Form 2220-1 (9-73)

PB82-101676

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EPA-600/2-81-179
September 1981

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MUNICIPAL ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

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PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE 1980-680-639
TYPING GUIDE SHEET

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FOREWORD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexicity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

In rural areas with poor or shallow soils, development is often limited by lack of means for adequate, safe wastewater disposal. Many attempts have been to develop wastewater disposal systems which are independent of soils.

In 1977, a prototype mechanical device for evaporating septic tank effluent was studied at the University of Colorado. Variables affecting the performance of the Rotating Disk Evaporator (RDE) were examined, and data collected on operation of the unit. As the preliminary technical findings were optimistic, a follow up study was performed to more adequately determine the potential market for such a device, and to estimate production and distribution costs. The results of that study are described in this report.

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Director
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Research Laboratory

ABSTRACT

Recent EPA-funded research into the on-site, mechanical evaporation of wastewater from single family homes revealed that a rotating disk evaporator (RDE) could function in a non-discharging mode. Such a device has potential use where site limitations preclude conventional methods for on-site disposal.

This report documents a marketing analysis made of the RDE. The marketing analysis defined the market potential for RDE systems, developed a practical design, estimated production and installation costs, and refined market estimates based on cost comparisons.

A small unit suitable for only the most favorable climates would have an FOB factory selling price of about $10,000 if fabricated with aluminum disks. Distribution costs and freight will amount to about $3,300. An additional $8,000 is required for installation (including a large storage tank for periods when freezing prevents evaporation), resulting in a total capital cost of about $22,000. Including amortized capital costs and O&M costs, an RDE system would treat household wastewater for about 3.4 cents per gallon.

Because of these high costs, the potential RDE market is quite small. It is limited to very expensive homes, second homes with no winter occupancy, and high cash flow - low sewage flow commercial establishments. Furthermore, unfavorable climatic conditions eliminate much of the nation from consideration. In summary, it is unlikely that Manufacturers of RDE systems would collectively generate national sales of 100 units per year.

This report was submitted in fulfillment of Contract No. 68-03-2738 by Environmental Resources Management, Inc. under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from September 14, 1978 to May 14, 1979, and work was completed as of January 15, 1980.

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ACKNOWLEDGEMENT

Key employees of Met-Pro Corporation, a manufacturer of complete wastewater treatment systems for small flows, served as consultants on this project. Mr. Robert M. Smith, P.E. (Vice President), Mr. William Stahl (Plant Manager), and Mr. Graydon Underwood (Engineering Manager) completed the tasks dealing with production engineering and determination of production costs.

Gregory Scott Hyatt, R.A., a residential construction architect, determined the installation costs of an RDE system in cooperation with general contractors.

SECTION 1

INTRODUCTION

BACKGROUND

A number of U.S. Environmental Protection Agency research projects have addressed alternative on-site wastewater treatment systems. The University of Colorado completed in 1978 a project concerned with disposal of septic tank effluent by evapotranspiration and by mechanically assisted evaporation.

The University of Colorado research project indicated that a rotating disk evaporator (RDE) could function as an on-site disposal method for many areas of the nation where site restrictions preclude the use of other disposal techniques. Furthermore, preliminary cost data suggested the system may be competitive with other on-site disposal alternatives.

OBJECTIVES OF PROJECT

To assist in determining if a full-scale demonstration of the RDE device is appropriate, the EPA retained Environmental Resources Management, Inc. (ERM) to accomplish the following:

a. Review the results of the University of Colorado research.

b. Define the market potential for non-discharging RDE systems with primary emphasis on unclustered, single family residential construction.

c. Determine needed changes in the system design of the RDE and in the choice of materials used to fabricate RDE units.

d. Determine the installed and O&M costs of the RDE system.

e. Refine the market estimates of RDE systems based on cost comparisons with other on-site alternatives.

SECTION 2

CONCLUSIONS

The rotating disk evaporator (RDE) provides for complete disposal of septic tank effluent without discharge to ground or surface waters. This potentially allows the use of RDE systems for the following applications:

a. New Construction - single family housing, second homes, and commercial establishments constructed without public sewers and on lots not suitable for conventional soil disposal systems.

b. Existing Construction - retrofits to correct malfunctioning soil absorption systems.

Climatic conditions affect the operation of the RDE system. These conditions limit the geographic market to 16 states in the South and West. Based on preliminary estimates of soil suitability and an analysis of projected housing in this geographic area, the potential market for mechanical-based units ranges from 8,000 to 32,000 units per year. Of this market, RDE applications could capture about 1,000 units per year, exclusive of cost considerations.

The 16-state geographic market area could be served effectively by three standard sizes of RDE units in some combination with three standard sizes of vault storage. An analysis of production, distribution, and installation costs reveals the smallest sized systems, i.e., located in an area with more favorable climatic conditions, would have capital costs of about $22,000 for a single household application. Adding O&M costs, the total costs of the smallest RDE system amount to $0.034 per gallon or approximately $2,800 per year. The largest sized system has a capital cost of $36,000.

These costs are based on a RDE unit fabricated with aluminum disks. The use of plastic disks could reduce the FOB factory selling price by 50 percent and the total costs to about $0.025 per gallon. However, the use of plastic disks necessitates design features which increase the opportunity for system failure and which may also impede evaporation.

Even with plastic disks, the RDE system is many times more costly than discharging-type, atlernative on-lot sewage disposal systems. The potential market for residential applications is very small, limited to expensive homes constructed on soils unsuited for discharge of total wastewater flow.

The RDE system has some potential application in the commercial market for high cash flow, low sewage flow establishments such as convenience food stores and quick food restaurants. Some highly profitable, potential locations for these establishments are unsewered sites with soils unsuited for discharge.

Substantial reduction of wastewater flow through the use of water conservation techniques could increase the RDE market somewhat. Nevertheless, it seems unlikely that a manufacturer could generate annual sales of more than 100 RDE units.

SECTION 3

RECOMMENDATIONS

A demonstration project is not recommended because even with a successful demontration, the potential market will remain insignificant in volume and limited in geographic coverage.

Before making a definitive decision with regard to a demonstration project, the EPA should communicate the results of this study with potential manufacturers.

If the EPA deems demonstration of RDE technology is warranted based on other considerations, a study should be made prior to the demonstration to determine the feasibility of using plastic disks.

SECTION 4

REVIEW OF UNIVERSITY OF COLORADO RESEARCH

RESEARCH AND DEVELOPMENT OF RDE CONCEPT

The EPA sponsored a research project by the University of Colorado dealing with sewage disposal by evaporation-transpiration. The work was performed over the period 1975 to 1978 and reported by Bennett and Linstedt.[1]

The research initially addressed only evapotranspiration beds. As the study proceeded, the EPA added to the scope of work an evaluation of two designs for mechanical evaporation of septic tank effluent. The RDE design proved more effective than a design featuring forced air evaporation.

FUNCTION DESIGN OF RDE UNIT

The RDE unit features a row of parallel disks mounted perpendicularly to a rotating horizontal shaft. The disks are partially submerged in a basin containing septic tank effluent. As the disks rotate in the vertical plane, the effluent adheres to the disks and evaporates to the atmosphere.

The main advantage of evaporation is that it provides for complete disposal of sewage without discharge to ground or surface waters. This allows the use of a site otherwise limited by such conditions as highly impermeable soils or steeply sloping topography.

The RDE unit increases substantially the effective evaporation surface for a small rainfall catchment area. Therefore, the RDE unit can function as a non-discharging system in regions characterized by other than arid and semi-arid climates, e.g., areas with high evaporation potential, but with significant precipitation.

CLIMATIC FACTORS

Bennett and Linstedt determined that the three most important climatic factors in operating an RDE unit are:

- o wind speed
- o humidity deficit
- o temperature

The driving force for evaporation is the humidity deficit achieved by wind movement of unsaturated air over the disks. Bennett and Linstedt reported that wind movement of unsaturated air accounts for about 95 percent of the evaporation from an RDE unit.

Temperature is important in the sense that when ambient temperature drops below 40°F, water on the disks freezes. During low temperature periods, wastewater inflow must be held in storage.

DEFINITION OF DESIGN FACTORS

Bennett and Linstedt developed two separate equations for determining RDE evaporation rates. One equation involves calculations of humidity deficit and wind speed. A less complicated equation is a correlation between potential RDE evaporation rate per unit wetted area and the standard Class A pan evaporation rate. Bennett and Linstedt obtained a relatively good correlation of RDE evaporation equal to 42 percent of pan evaporation.

MACHINE VARIABLES

In evaluating the RDE, the University of Colrado analyzed a number of machine variables and determined the following optimal value:

1. Rotational speed: 0.5-1 rpm
2. Submergence of disk: 71% of radius measured from outer edge
3. Disk spacing: about 1" (2.5-3.0 cm)
4. Disk color: darker color slightly more effective
5. Disk diameter: no effect
6. Disk material: no significant effect

ADDITIONAL RESEARCH NEEDS

The Bennett and Linstedt report is rather complete. Nevertheless, there are some issues which should receive study if the project proceeds into a demonstration phase.

The research did not study the effect of annual variation of evaporation rates and how this would affect the size of the RDE unit and the size of the storage reservoir. Bennett and Linstedt incorporate an intuitively estimated safety

factor in their design method to compensate for variations in evaporation potential and other factors.

Bennett and Linstedt addressed only briefly the problem of build-up of dissolved solids and suspended solids in the storage reservoir. Their conclusion is that the build-up of solids would require periodic emptying of the storage reservoir contents and disposal at conventional sewage treatment plants.

Other issues which require study before the commercialization of an RDE unit include development of a design method suitable for sanitarians (graphical method presented by Bennett and Linstedt does not yield easily replicated results), optimization of tradeoff between number of disks and size of storage, potential problems with odors, optimization of alignment of disks (perpendicular to prevailing wind direction may be inappropriate if based in part on winter winds when RDE units are inoperable), and effect of topography, vegetation, and nearby structures on wind movement and evaporation rates.

SECTION 5

ESTIMATE OF POTENTIAL MARKET

STATES SUITABLE FOR RDE

Two independent climatic conditions affect the applicability of the RDE device:

- o Evaporation Rate
- o Temperature

Disk area varies inversely with evaporation rate. The amount of storage required varies directly with the number of annual days in which the temperature drops below 40°F.

Disk area and storage requirements obviously have substantial impact on the cost of a RDE unit. To indicate, on an initial basis, the areas of the nation where climatic conditions support the use of a RDE, two criteria were developed:

a. Normal annual pan evaporation is equal to or greater than 40" (representing an average potential disk evaporation rate of 0.05 L/hr.m^2).

b. There are no more than 50 days with mean daily temperature on an annual smooth course less than 32°F. (Depending upon severity of temperature variations, having 50 days with mean daily temperature below 32°F could prohibit disk utilization for over 100 days.)

Using climatic data readily available from standard references[2], Figure 1 was prepared to show the regions of the United States which satisfy both criteria.

Table 1 indicates states, based on Figure 1, where RDE systems are viable from a climatic perspective, i.e., the RDE unit evaporation rate and the required storage are within the initial criteria. Table 1 includes percentage figures for three states to indicate that portion of the state suitable for a RDE unit. Some states were eliminated if the majority of the population is situated outside the defined market area.

Normal Annual Pan Evaporation = 40 in.
Normal Annual Number of Days With Mean Temperature (Smooth Annual Course) Below 32°F = 50

Figure 1. Delineation of Temperature and Evaporation Criteria

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TABLE 1. STATES SUITABLE FOR RDE

Arizona	Mississippi
Alabama	New Mexico (50%)
Arkansas	North Carolina
California	Oklahoma
Florida	South Carolina
Georgia	Tennessee
Kentucky (75%)	Texas
Louisiana	Virginia (50%)

CHARACTERISTICS OF POTENTIAL RDE MARKET

The potential market for the RDE system within the defined geographic market is essentially that of alternatives to conventional septic tank-soil absorption systems.

a. New Construction - single family housing, second homes and commercial establishments constructed without public sewers and on lots not suitable for conventional soil disposal systems.

b. Existing Construction - retrofits to correct malfunctioning soil absorption systems.

NEW SINGLE FAMILY CONSTRUCTION

The Forest Products Laboratory of the U.S. Department of Agriculture made projections of new single-family housing for the period 1978 to 2020. Marcin[3] presented these nationwide projections on an annual basis, disaggregated into four regions: South, West, Northeast, North Central. Figure 2 shows the coverage of these four regions.

The annualized projections made by the Forest Products Laboratory were totaled for ten year periods for the South and West regions, the only two regions with states within the RDE geographic market.

Because portions of the South and West regions lie outside the RDE geographic market, it was necessary to estimate the percent of regional housing starts in the RDE geographic market. To estimate this split of regional housing, housing authorized during July 1978 and November 1978 [4,5] was analyzed on a state-by-state basis. This analysis suggested

Figure 2. Regions for Making Housing Projections

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that 77 percent of the housing starts in the South region are situated within the RDE geographic market. Likewise, the value for the West region is 58 percent.

These two percentage factors were applied to the Forest Products Laboratory projections to indicate the total number of housing units projected for the RDE geographic market. Table 2 shows this information.

TABLE 2. NEW SINGLE FAMILY HOUSING IN RDE GEOGRAPHIC MARKET

Period	Nationwide Total	Projected for RDE Geographic Market*	
		South	West
1981-1990	16,400,000	5,700,000	2,400,000
1991-2000	14,800,000	5,500,000	2,300,000
2001-2010	14,200,000	5,200,000	2,000,000
2011-2020	13,900,000	5,000,000	1,900,000
	59,300,000	21,400,000	8,600,000

* See Table 1 for specific states included.

SECOND HOME CONSTRUCTION

The Forest Products Laboratory Projections also addressed second homes; however, these nationwide estimates were not disaggregated. To disaggregate into RDE geographic markets, percentage factors were applied. For the South region, nationwide totals were multiplied by 36 percent (percent of nationwide total housing units constructed in the RDE South geographic market, see Table 2). Likewise, a percentage factor of 15 percent was used for the West.

Table 3 disaggregates the nationwide second home totals into the RDE geographic market. These estimates exclude second homes to be constructed outside the geographic market area; however, RDE units are potentially viable for some of these homes if not permanently occupied. Thus, the potential market of second homes may be slightly larger than shown in Table 3.

TABLE 3
NEW SECOND HOME CONSTRUCTION IN RDE GEOGRAPHIC MARKET

Period	Nationwide Totals	Projected for RDE Geographic Market*	
		South	West
1981-1990	687,000	250,000	100,000
1991-2000	888,000	320,000	130,000
2001-2010	860,000	310,000	130,000
2011-2020	599,000	220,000	90,000

* See Table 1 for specific states included.

COMMERCIAL CONSTRUCTION

Data on commercial construction, at least data readily usable for this study, are not available. The information provided by governmental agencies is too general to define situations where a RDE system is a viable alternative. To obtain this information will likely require the services of a private firm specializing in such activities.

NEW CONSTRUCTION REQUIRING ALTERNATIVE SYSTEMS

Tables 2 and 3 list the new single unit housing projected for RDE geographic markets. There is no quantitative information available to translate these projections into how many houses will be constructed on public sewers and how many of those will be constructed on lots not suitable for conventional soil disposal systems. Therefore, it is necessary to estimate the range of the potential market, i.e., bracket the market with two estimates, one high and one low.

Low Estimate

The low estimate is defined by the historic trend of alternative system installations. Recent growth of sewer moratoria will increase the need for alternative systems, especially in price inelastic markets such as commercial establishments and high priced housing. More stringent enforcement of regulations governing the construction of conventional soil disposal systems and, of course, the availability of an economically viable alternative system would increase the demand for alternative systems.

Personal communication with the Alternative Wastewater Management Association reveals that 125,000 on-site, mechanical-based alternative systems were installed over the past ten years. Of this total, about 100,000 were the rather inexpensive aeration type. Even when wrongfully assuming all these units were installed on new housing (many were commercial applications), mechanical alternative systems captured about one percent of the new housing market. A figure of one percent thus seems reasonable as a low estimate considering the recently increased national interest in individual wastewater systems.

High Estimate

The high estimate of the potential market range was determined by making seemingly inflated estimates of two variables:

1. Percent of housing units to be constructed off public sewers;

2. Percent of non-sewered housing on lots not suitable for conventional soil disposal systems.

Some rather detailed information is available on historic trends for the first variable. Table 4 summarizes 1970 census data for each state in the RDE market for housing units constructed on septic tanks.

County-by-county information was organized into SMSA and non-SMSA data in view of differences in sewer availability and land availability. An analysis of privately owned housing units completed for the period 1968 to 1977 was made from U.S. Department of Commerce data[6] to determine the split in SMSA and non-SMSA housing as shown in Table 5.

TABLE 5. SMSA AND NON-SMSA HOUSING CONSTRUCTION

Percent of Units Inside SMSA's	71%
Percent of Units Outside SMSA's	29%

TABLE 4. HOUSING UNITS ON SEPTIC TANKS

Region	State	SMSA Counties	Non-SMSA Counties	Statewide
South	Alabama	32%	39%	35%
	Arkansas	24%	38%	33%
	Florida	34%	56%	38%
	Georgia	24%	45%	32%
	Kentucky	24%	34%	29%
	Louisiana	15%	42%	25%
	Mississippi	25%	31%	30%
	North Carolina	35%	48%	42%
	Oklahoma	16%	28%	22%
	South Carolina	39%	44%	42%
	Tennessee	41%	30%	35%
	Texas	11%	34%	17%
	Virginia	21%	32%	27%
	Weighted Average	25%	39%	
West	Arizona	14%	37%	20%
	California	9%	43%	12%
	New Mexico	17%	22%	20%
	Weighted Average	9%	38%	

It is only possible to make gross estimates of lots not suitable for conventional on-site disposal systems. Where no reasonable basis was available, estimates tended to be high to indicate maximum market size. In this theme, the following assumptions were made:

a. 70 percent of new single family housing will be constructed within SMSA counties (see Table 5).

b. 25 percent of new SMSA housing in the South will be constructed off public sewers (see Table 4).

c. 10 percent of new SMSA housing in the West will be constructed off public sewers (see Table 4).

d. 10 percent of unsewered, new SMSA housing will be constructed on lots requiring mechanical-based alternative systems (no basis; contractor's estimate to indicate maximum market size).

e. 40 percent of new, non-SMSA housing in the RDE geographic market will be constructed off public sewers (see Table 4).

f. 5 percent of unsewered, new non-SMSA housing will be constructed on lots requiring mechanical-based alternative systems (no basis; contractor's estimate to indicate maximum market size).

g. 67 percent of new second homes will be constructed off public sewers (no basis; contractor's estimate to indicate maximum market size).

h. 33 percent of unsewered, new second homes will be on lots requiring mechanical-based alternative systems (no basis; contractor's estimate to indicate maximum market size).

Application of these factors to data developed in previous tables yields the potential RDE market for new housing shown in Table 6. These figures suggest that mechanical-based alternative systems could potentially capture about three percent of the new single family housing constructed within the RDE geographic market area.

A three percent share of the market is much higher than the historic share of less than one percent. It is evident that these projections are sensitive to the assumptions made above, especially those assumptions regarding lots unsuitable for conventional systems. These assumptions are believed to represent the maximum market penetration, and thus the market has been bracketed between the three percent estimate as a "high" and the historic share of one percent as a "low".

TABLE 6. POTENTIAL NEED FOR MECHANICAL-BASED SYSTEMS FOR NEW SINGLE FAMILY HOUSING WITHIN RDE GEOGRAPHIC MARKET AREAS

	Time Horizon	Primary Residence Inside SMSA	Primary Residence Outside SMSA	Second Home	Total
South	1981-1990	100,000	30,000	60,000	190,000
	1991-2000	100,000	30,000	70,000	200,000
	2001-2010	90,000	30,000	70,000	190,000
	2011-2020	90,000	30,000	50,000	170,000
West	1981-1990	20,000	10,000	20,000	50,000
	1991-2000	20,000	10,000	20,000	60,000
	2001-2010	10,000	10,000	30,000	50,000
	2011-2020	10,000	10,000	20,000	40,000

REMEDIAL RETROFITS

Retrofits, a relatively new market for mechanical-based systems, would add to the previous estimates. The potential market for remedial retrofits is even more obscure than new construction. The market obviously depends on federal funding, assertiveness of regulatory agencies in requiring the correction of malfunctioning systems, sewer system extensions, and the number of existing malfunctioning systems which are not amenable to restoration or replacement by conventional systems.

As a high estimate, it is assumed that two percent of all existing houses with septic tanks will require, within the next twenty years, an alternative system. For new housing constructed with septic tanks, it is assumed that one percent will require an alternative system within the first twenty years after construction.

Table 7 shows the potential market for remedial retrofits based on the above assumptions and data in Tables 2 and 4. The figures represent average values over the next twenty years.

TABLE 7. POTENTIAL MARKET FOR REMEDIAL RETROFITS

Region	Existing Housing	Future Housing
South	5,000/year	1,000/year
West	1,000/year	---

SUMMARY OF POTENTIAL RDE MARKET

Tables 6 and 7 indicate the maximum potential market for mechanical-based alternatives for new housing and remedial retrofits within the RDE geographic market area. These tables do not include the potential market for commercial applications; however, the magnitude of the commercial market appears small in comparison.

From Tables 6 and 7 it can be seen that the maximum potential market over the next twenty years is as follows:

South	25,500 units/year	Total 32,000/year
West	6,500 units/year	

The low estimate of one percent of new housing translates to about 8,000 units per year. This range of 8,000 to 32,000 units per year represents the potential market for mechanical-based systems.

Within the wastewater treatment business, rarely does a particular manufacturer capture a major portion of the market for any product. While this is not true for the mechanical-based alternative on-lot systems market, relatively new products in this market have captured only a small share. It is unlikely that a RDE product would make a major penetration. A very strong marketing program would likely be required to gain as much as ten percent of the market over the next twenty years.

Based on the above, and considering that the market estimates are purposely high, the potential market for RDE units is about 1,000 units per year excluding cost considerations.

SECTION 6

DESIGN OF RDE UNIT

CONFIRMED AND UNCONFIRMED DESIGN FEATURES

As we discussed in Section 4 of this report, the University of Colorado research determined the optimal operating characteristics for disk submergence, rotational speed, disk spacing and disk color. Certain design features remain unconfirmed, at least to the degree that they affect the installed and O&M cost of a RDE unit. Of particular significance in this regard are disk material and disk diameter.

NON-MONETARY CONSIDERATIONS

Design features affect the marketability in ways other than cost. Not satisfying constraints such as ease of installation, reliability, shipping restrictions, institutional aspects, and aesthetics will prevent successful marketing of RDE systems.

Ease of Installation

Ease of installation is very important. Home builders and septic tank installers should not have to use special equipment in delivering, off-loading, and placing the RDE units. The weight of the unit should not exceed the capacity of the truck frame and crane used to delivery pre-cast septic tanks.

The unit itself should be pre-assembled so that the contractor has minimal requirements for field assembly. It is best if the contractor can lift a completely assembled RDE unit off the delivery truck and place it immediately into final position. If excess weight proves a problem, e.g., exceeding crane capacity, the unit should be delivered to the construction site in no more than two parts: tank complete with shaft supports and shaft complete with disks.

Reliability

The unit should require minimal maintenance. Specialized maintenance would likely go unattended by home owners. Management districts may provide sufficient maintenance if RDE units are widely used and not a special application for two or three residences in the district. Likewise, widespread use may support private maintenance contracts.

Shipping Restrictions

Shipping the unit pre-assembled from the factory would likely make width restrictions more constraining than weight restrictions. This limits either the number of disks for a RDE unit or the disk diameter.

Aesthetics

The large size and exposed equipment inhibit the use of RDE systems on small lots. Screening the unit with plantings would restrict wind movement, the driving force for RDE evaporation.

Overcoming the aesthetic problem represents a difficult undertaking in the sense that the disks must be exposed. One possibility is a roof-top installation designed with achitectural integrity. While such an installation is also more efficient due to higher wind velocities at roof-top level versus ground levels, this method faces problems with building codes and its weight may exceed the capacity of standard framing members.

OPTIMIZATION OF DESIGN FEATURES

Selection of Disk Material

Possible materials for the construction of disks are limited to two basic classes - metals and plastics. The plastic material would be an expanded polystyrene (although somewhat susceptible to damage during handling), similar to that originally used for rotating biological contactors. Of the different metals, aluminum has more obvious advantages.

Considering disk material costs only, aluminum is six to eight times more expensive than plastic. Nevertheless, the use of plastic severely complicates the anchoring of disks to the drive shaft. Turning moment about the shaft would tend to soften openings, and creep and outright failure could occur.

Such problems plagued the earlier installations of rotating biological contactors used for secondary treatment of wastewater. These early problems have now been minimized in two different ways:

a. Some manufacturers use elaborate metal supports to anchor plastic media to the shaft.

b. One manufacturer does not use metal supports and instead alternates thermally bonded flat and corrugated plastic sheets.

The use of either method for anchoring RDE disks would impede substantially the movement of wind past the disks (the primary driving force for evaporation).

The method of alternating flat and corrugated sheets limits air inflow to narrow, radial passages. Although this design functions satisfactorily in sustaining attached biomass, it apparently would severely reduce evaporation rate of a RDE unit.

If plastic were used as disk material, the design for anchoring the disks would likely feature metal supports rather than thermally bonded flat and corrugated sheets. However, the metal supports used for rotating biological contactors typically include several metal members running parallel with the shaft. These members would reduce the clear cross-sectional space between disks of a RDE and reduce wind movement accordingly. Furthermore, the use of metal supports increases the opportunity for structural failure.

The effect of elaborate metal spiders on evaporation rates was not evaluated by Bennett and Lindstedt. Because the reduction in evaporation rate is unknown, and because the added costs of spiders could offset the reduced material costs of substituting plastic disks for aluminum disks, aluminum is selected for purposes of estimating production costs. Nevertheless, the cost estimates presented subsequently in this report include a cursory analysis of the sensitivity of total costs to substituting plastic for aluminum.

Selection of Disk Diameter

Mill standard for aluminum is 48-inch wide material. Any width larger than this would represent a higher cost, with unit costs remaining about the same for all widths up to about 96 inches.

Bennett and Linstedt used a diameter of 78 inches in sizing RDE systems. A 48-inch diameter disk provides only 37 percent of the evaporation area per disk as that of a 78-inch diameter disk. This would necessitate RDE units nearly three times longer than that required for 78-inch diameter disk. For the RDE units designed by Bennett and Linstedt, 48-inch diameter disks would yield units over 20 feet long. This is unacceptable when considering ease of installation and evaporation efficiency (the 48-inch disks are lower and thus more affected by wind drag of earth's surface).

The 78-inch diameter size selected by Bennett and Linstedt seems reasonable when considering all aspects. Nevertheless, a more detailed analysis of cost, aesthetics, ease of installation, and operation efficiency may suggest a larger diameter disk is appropriate. However, to keep within standard width restrictions for highway shipments, disk diameters greater than 90 to 96 inches should not be considered.

Components of RDE Unit

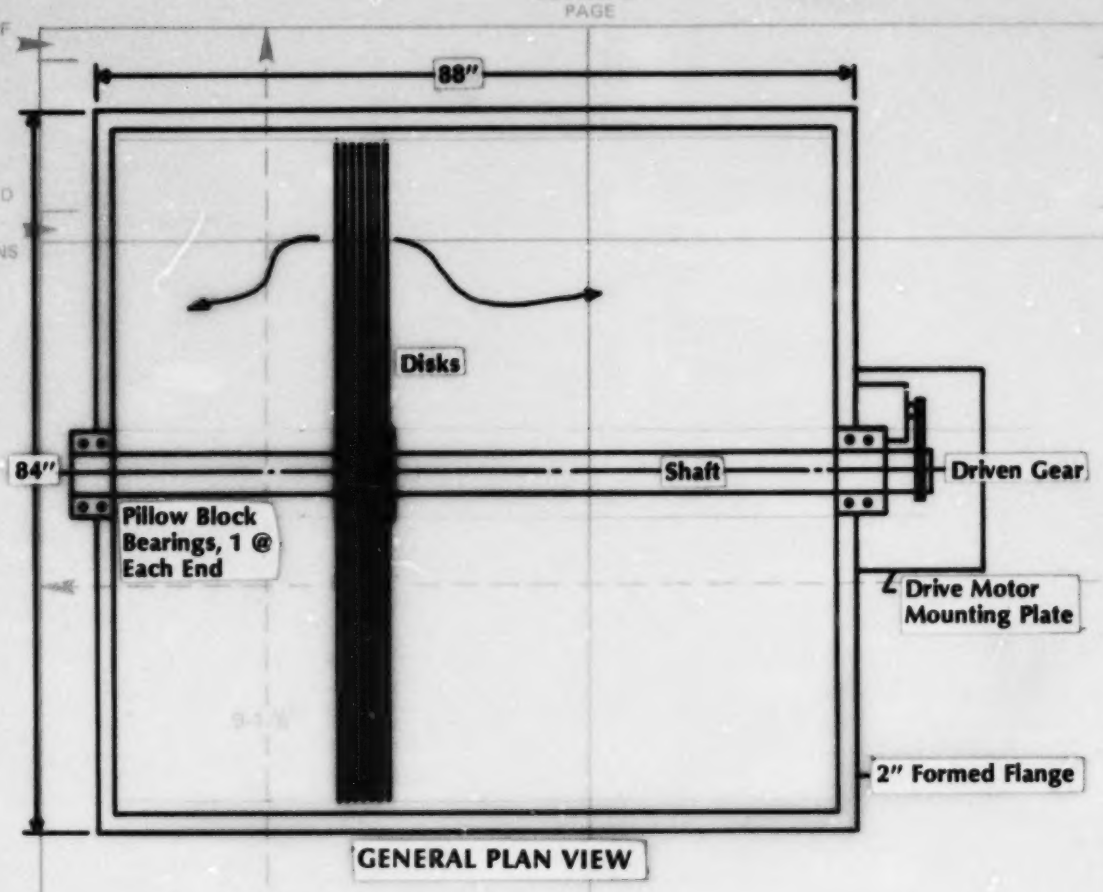
Figure 3 shows the basic configuration for a RDE unit. Its components, component functions, and component specifications are listed in Table 8. The table specifies components which collectively make a RDE unit that is readily installed, high reliable, and easily maintained without excessive costs.

DETERMINATION OF RDE SYSTEM SIZE

Design Flow

The selection of a design flow is an initial consideration in sizing a RDE system. In regulating on-lot systems, public agencies use design flows severely inflated to include a safety factor. A typical design flow used by regulatory agencies is 150 gallons per bedroom per day (two persons per bedroom).

On the other hand, detailed flow studies[7] have shown that sewage flow from a household is about 45 gpcd. For the typical population figure of 3.5 persons per household, this would yield a flow of 160 gpd. This differs substantially from a regulatory agency design flow of 450 gpd for a three-bedroom house.



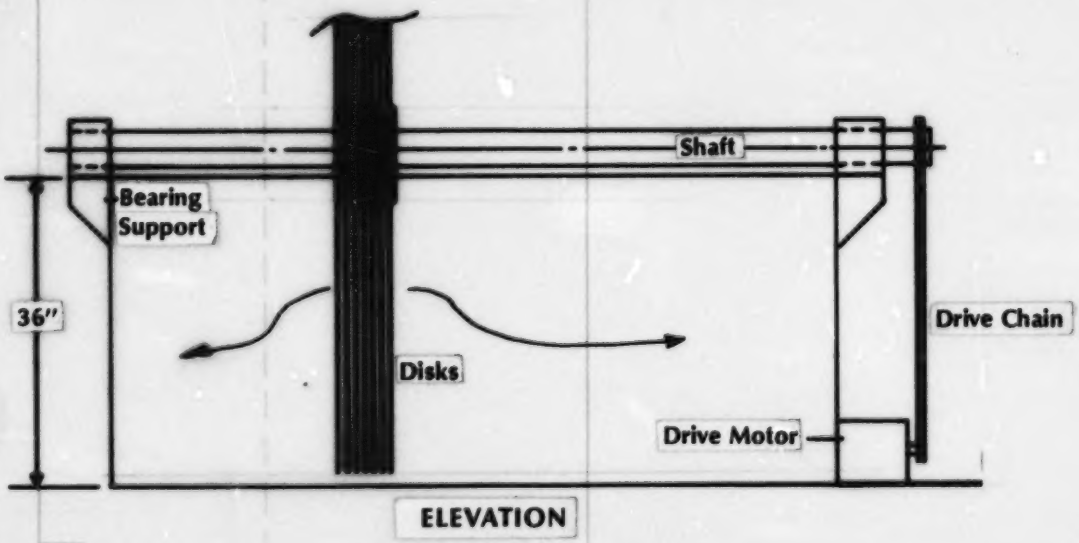


Figure 3. Plan and Elevation of 80-Disk Unit

TABLE 8. RDE COMPONENT SPECIFICATIONS

Component	Component Function	Component Specification
Shell	Forms the tank to maintain liquid contact with the rotating disk.	Rectangular 3/16" carbon steel plate sides, ends, bottom drive mounting plate; sides and ends have 2" formed flange.
Supports	Situated beneath the tank to support it on top of a pad.	4" carbon steel channel.
Disks	Disks required to provide the evaporation surface.	Aluminum, 5052-H34, 1/16" thick, cut from 78" x 78" squares.
Shaft	Supports and drives the disk.	5" x 5" square, hollow, structural, carbon steel tubing.
Spacers	Separate disks so that wind passes unimpeded over the evaporation surfaces.	Aluminum extrusion of same material as disks, cut and deburred, next size larger than shaft, 7/8" long.
Stub ends/ intermediate supports	Support the shaft.	Machined 4-1/2" diameter cold rolled carbon steel bar stack.
Drive unit	Turns the shaft.	Triple reduction, worm gear speed reducer (1000:1 ratio) with chain drive to shaft of RDE; additional reduction of 1.8 taken through shaft mounted sprocket; 1750 RPM, 1/2 HP motor; chain guard.
Bearings	Support the revolving shaft.	Split, pillow block, 4-1/4" diameter.
Coating	Required on all exposed steel surfaces.	6 to 12 mils coal tar expoxy interior (wetted surfaces), 4 to 6 mils epoxy exterior.

Recognizing that design flow has a substantial impact on RDE costs, and that RDE systems would likely incorporate flow conservation measures in the household, it was decided to use a design flow of 225 gallons (850 liters) per day. This design flow represents a compromise between average flow based on field measurements and flow rates used by regulatory agencies for design purposes. Bennett and Linstedt[1] demonstrated that this flow corresponds to a family of two adults and four children.

Sizing of System for Specific Locations

After selecting a design flow, the approach taken to establish a RDE system size involved designing RDE-storage systems for particular locations throughout the nation. Locations were selected both within and outside the geographic market area defined in Figure 1.

The following locations, monthly pan evaporation rates and average monthly temperatures were obtained from the NOAA series of publications, "Climatological Data Annual Summary":

Billingame, California	Wanship Dam, Utah
Holland, Virginia	Martin Dam, Alabama
Medford, Oregon	Athens, Georgia
Laven, Texas	Fairhope, Alabama
Dixon Dam, Kentucky	

In addition, three locations were studied using data presented by Bennett and Linstedt:

Hialeah, Florida
Boulder, Colorado
Canton, New York

It was found that the design method proposed by Bennett and Linstedt gives non-replicative results. Rather than using the graphical techniques suggested by Bennett and Linstedt, it was necessary to use a mathematical technique.

The procedure used in sizing the RDE-storage system (which follows basically the same method as presented by Bennett and Linstedt) is as follows:

a. Determine monthly evaporation for RDE using pan correlation factor.

b. Apply a utilization factor to determine RDE evaporating rate. (Utilization factor reflects freezing periods, and the value of 1.0 represents a full-time operation. For monthly mean temperatures of 35°, 40° and 45°, utilization factors of 0.25, 0.5 and 0.75 were used respectively.)

c. Sum monthly RDE evaporating rates and divide by 12 to determine the maximum average loading rate.

d. Determine storage required per unit size of RDE by subtracting maximum average loading rate from monthly RDE evaporating rates and multiplying the remainder by number of hours in the month.

e. Determine RDE size by dividing RDE maximum average loading rate into design flow.

f. Determine storage size by multiplying unit storage required times RDE size.

Table 9 illustrates these tabulations for Holland, Virginia. Table 10 shows the RDE size and storage required for the chosen locations. The figures do not include any safety factor.

TABLE 9. RDE EVAPORATION - STORAGE TABULATIONS

HOLLAND, VIRGINIA

Month	Pan Evaporation (in/mo.)	Pan Evaporation ($L/hr \cdot m^2$)	Potential Disk Evaporation ($L/hr \cdot m^2$)	RDE Utilization Factor	RDE Evaporating Rate ($L/hr \cdot m^2$)	RDE Evaporation Rate Deficit ($L/hr \cdot m^2$)	Unit Storage Required (L/m^2)
J	2.73*	0.096	0.040	0.75	0.030	0.040	30
F	3.77*	0.132	0.055	0.75	0.042	0.028	19
M	4.62	0.162	0.068	1.0	0.068	0.002	1
A	6.42	0.225	0.094	1.0	0.094	--	--
M	6.98	0.244	0.103	1.0	0.103	--	--
J	7.73	0.271	0.114	1.0	0.114	--	--
J	7.69	0.269	0.113	1.0	0.113	--	--
A	6.60	0.231	0.097	1.0	0.097	--	--
S	4.92	0.172	0.072	1.0	0.072	--	--
O	3.57	0.125	0.052	1.0	0.052	0.018	14
N	2.53	0.089	0.037	1.0	0.037	0.033	24
D	1.51*	0.053	0.022	0.75	0.017	0.057	42
					0.839		130

Maximum average loading rate = 0.839 ÷ 12 = 0.07 $L/hr \cdot m^2$

*Interpolated values

TABLE 10. RDE - STORAGE SYSTEM DESIGN SIZES

Location	Maximum Average RDE Evaporation Rate ($L/hr \cdot m^2$)	Number of Disks*	Unit Storage Required (L/m^2)	Storage Required (L)
Billingame, California	0.07	118	160	81,000
Holland, Virginia	0.07	118	140	71,000
Medford, Oregon**	0.05	165	200	140,000
Laven, Texas	0.11	75	200	64,000
Dixon Dam, Kentucky	0.045	183	120	94,000
Wanship Dam, Utah**	0.06	137	200	120,000
Martin Dam, Alabama	0.055	150	81	52,000
Athens, Georgia	0.075	110	120	57,000
Hialeah, Florida	0.090	92	85	34,000
Boulder, Colorado	0.100	82	310	110,000
Canton, New York**	0.045	183	130	110,000
Fairhope, Alabama (1975)	0.055	150	84	54,000
Fairhope, Alabama (1977)	0.065	127	112	61,000

*Based on 850 L/day (225 gal/day) design flow, 4.3 m^2 exposed surface area per disk (78-inch diameter, 28-inch submergence), and exclusive of any safety factor.

**Outside RDE geographic market defined by Figure 1.

STANDARDIZATION OF RDE SIZE

The commercialization of a RDE will require the selection of standard sizes. Table 11 defines three sizes of RDE units and storage which offer a sufficient range to cover the geographic market area (based on sizes required for various locations).

TABLE 11. STANDARD RDE SYSTEM SIZES

Item	Standard Size
Storage	37,850 liters (10,000 gallons)
	56,775 liters (15,000 gallons)
	75,700 liters (20,000 gallons)
RDE Unit	80 Disks
	110 Disks
	140 Disks

SECTION 7

COSTS OF RDE SYSTEMS

FABRICATION COSTS

A production engineering analysis was made for fabricating the three design sizes of 80, 110, and 140 disks at annual production levels of 100, 1,000 and 10,000 units. These lower and upper production levels represent one order of magnitude difference from the estimated potential market of 1,000 units per year.

Fabrication Steps

Whether 100 or 10,000 units were produced at a single plant per year, the fabrication of an RDE device would proceed essentially the same. Basically, the manufacturing involves the purchase of steel and aluminum directly from mills, the purchase of drive components as complete units, and the following fabricating steps:

1. Blank out 78" diameter disks from 78-inch square aluminum (resulting in a 21.5 percent scrap factor).

2. Punch square hole in center of disk (both blanking out the disk and punching a square hole will require a special 250 ton press, costing about $75,000).

3. Slip the disk and spacers on the shaft (in alternating fashion).

4. Machine solid steel stub ends and pin to the shaft tubing.

5. Fabricate the steel tank consisting of:
   a. Shear steel to size and square
   b. Form, fit, and weld manually the steel
   c. Sandblast and coat the steel (coating must follow sandblasting within 24 hours to prevent a rust blush appearing)

6. Mount drive motor plate, drive unit, and pillow block bearings to tank.

7. Place shaft to complete fabrication.

Breakdown of Estimated Fabrication Costs

Table 12 shows a detailed breakdown of the cost of fabricating 1,000 RDE units per year. The cost categories for producing the 80-disk units are as follows:

- Material - 51%
- Labor - 4%
- Factory overhead - 9%
- G&A - 11%
- Profit - 25%

Cost Impact of Substituting Plastic for Aluminum

If plastic were substituted for aluminum as disk material, the costs of disk material would be reduced substantially. Polystyrene disks would cost about $6.00 each, representing a $3,400 reduction in material costs for the 80-disk RDE. However, elaborate metal spiders are required with plastic disks and these are not included in the cost estimates shown in Table 12.

A hexagonal metal spider (three arms at about six feet each) with hub would weigh about 45 pounds if constructed of stainless steel. At $0.75 per pound, each spider, with fittings, would add about $35 to total material costs. Without detailed structural analysis, the number of spiders required is unknown. However, it is possible that as many as one per disk could be required. Such a maximum requirement would offset almost totally (when including added labor costs) the $3,400 reduction in disk material costs.

On the other hand, if a design could be developed featuring only five spiders per 80-disk RDE and six connecting rods, the metal supports could add as little as $300 to material costs. Even when including the increased labor, such a design could reduce the selling price (FOB factory) for an 80-disk unit to about $5,000.

It appears that this conceivably minimal design featuring plastic disks and five metal spiders could reduce the selling price of an 80-disk unit by 50 percent. Nevertheless, evaporation rate is reduced somewhat and it is not known if this minimal design is structurally sound. Before placing such a design in full production, more study and testing would be required than with a unit fabricated with aluminum disks.

TABLE 12. RDE ESTIMATED FABRICATION COSTS

Cost Component	Costs		
	80-Disk RDE	110-Disk RDE	140-Disk RDE
Aluminum Disks, 78" diameter, 1/16" = .716 lb/sf @ $1.60/lb = $48.50/disk	$ 3,880	$ 5,335	$ 6,790
Spacers	50	65	87
Shaft, 84", 113" and 144" long @ $0.30/lb	34	46	58
Stub Ends @ $0.26/lb	36	36	36
Intermediate Support @ $0.26/lb	--	17	17
Channel Supports @ $0.30/lb	36	46	56
Steel Plating for Tank @ $0.21/lb	273	328	382
Bearings	523	785	725
Large Gear	39	39	39
Small Gear	18	18	18
Chain	25	25	25
Drive Unit, complete	274	274	274
Paint, tar, grit	35	44	52
Subtotal, materials	$ 5,223	$ 7,062	$ 8,619
Labor @ $7/hr	$ 427	$ 553	$ 693
Factory Overhead	854	1,106	1,386
G&A	1,148	1,538	1,888
Profit (25%)	2,551	3,418	4,195
Selling Price, FOB Factory	$10,203	$13,677	$16,781

Costs of Other Production Levels

As noted, the estimated selling price is dictated primarily by the costs of material. Furthermore, the disks account for about 75 percent of total material costs.

These relationships among selling price, material costs, and labor costs reveal that more automation (which is possible with higher production) will have minimal impact on selling price. The key to selling price is the cost of materials, especially the aluminum for the disks.

The cost of materials shown in Table 12 is based on lowest mill prices available. Even at the level of 1,000 units per year, a factory should be able to obtain the lowest mill prices available for the various materials and components. Therefore, producing 10,000 units per year would not reduce material cost.

The only apparent economics that can result from producing 10,000 units per year would occur in reduced labor in the tank fabrication. All material could be sandblasted in the flat, fabricated, and then "touch-up" blasted. Building and assembly would still require manual operation; however, coating could be automated. This would save about five to ten hours per unit, a very small cost reduction.

Some cost savings can result in locating a manufacturing plant near both an aluminum mill and a steel mill. Freight is a substantial cost of aluminum and steel materials, and increasing quantities produces only minimal reductions in unit freight costs. However, it is unlikely that there are two compatible steel and aluminum mills in an area where a large demand exists for RDE units.

Rather than realizing savings in material and labor, a manufacturer producing 10,000 units at one plant could likely reduce factory overhead and G&A due to the dedication of a sizable portion of its operation to this one product. However, the very competitive nature of this type of fabrication would likely prevent a manufacturer from producing 10,000 units at one plant. If 10,000 units were to be produced per year, this would require about 800,000 hours of labor per year or 400 workers. In the metal fabrication business, it is unlikely that this number of workers would be involved in the manufacture of one item in one location in the country.

Economies of scale would not have a strong effect even at lower production levels. It is likely that producing 100 units per year would only increase the cost by about 10 to 15 percent.

DISTRIBUTION COSTS

The distribution channels for RDE units would differ depending on whether the market were residential or commercial construction. The most probable scenario for the residential market is that manufacturers would produce the units and ship truckload increments to a distributor who would sell directly to contractors or through dealers. Each level of distribution would add 25 to 35 percent onto their costs.

The commercial market would likely involve direct selling through agents with exclusive rights. Of course, the most effective distribution channel depends on factors such as total sales volume, competition, and range of customers.

As a minimum, the distribution of a RDE unit would add 30 percent to the FOB factory price exclusive of freight. Freight would be about $300 for 1,000 mile distances if shipped in increments of five units. Smaller shipments would necessitate higher freight costs.

INSTALLATION COSTS

Figure 4 shows the basic components of a complete RDE system. The installation of a RDE system can be accomplished by a contractor experienced in installing conventional onsite systems. The only exception is electrical hook-up which will require an electrician.

Table 13 shows the costs for installing a RDE system, exclusive of the cost of the RDE unit itself. The costs shown in Table 13 include the contractor's profit. The major installation cost is the fiberglass storage tank. Only retail prices were obtainable, and a 33 percent reduction was assumed.

TOTAL CAPITAL COSTS

The estimated capital costs of an installed RDE system featuring an 80-disk unit and 10,000 gallons of storage (the smallest sizes evaluated) are as follows:

RDE (FOB factory)	$10,200
Freight and Distribution	3,300
Installation	8,100
	$21,600

Figure 4. Typical Installation of RDE System

An 80-disk unit constructed with plastic disks and 10,000 gallons of storage would have installed costs of about $15,000. The estimated costs of an installed RDE system featuring aluminum disks and the largest sizes are as follows:

RDE	$16,800
Freight and Distribution	5,300
Installation	13,500
	$35,600

TABLE 13. INSTALLATION COSTS OF RDE SYSTEM

Item	Cost
Tank, septic, 1,000 gallons	$ 400
Tank, reservoir, fiberglass, 10,000 gallons	3,800[1]
Excavation	2,000[2]
Pipe, cast iron, 4" (20LF @ $9.50/LF)	200
Pipe, PVC, 4" (50LF @ $6.25/LF)	300
Pump w/level and temperature control	800
Pad, concrete	200[3]
RDE Unit Delivery and Placement	100
Electrical Hook-up	300
	$8,400

[1] Retail price less 33 percent. $5,500 for 15,000-gallon tank; $7,200 for 20,000-gallon tank.
[2] $3,000 for 15,000-gallon tank; $4,000 for 20,000 gallon tank.
[3] Add $100 for 110-disk unit, $100 for 140-disk unit.

O&M COSTS OF RDE SYSTEM

The number of items comprising the O&M costs of a RDE system are fairly insignificant. The two electrical motors (for the RDE drive and for the effluent pump) are small-powered units, and while they will operate almost continuously, their use of electricity is small. Parts replacement due to wear and tear is obviously minimal, considering the simplicity of the unit.

The only scheduled maintenance required is tightening of the chain in the drive unit, lubrication, and infrequent emptying of the storage reservoir due to solids build-up.

O&M costs are estimated as follows:

Mechanical parts replacement (5 percent of drive assembly, bearings and pump)	$100/yr
Electrical power ($.05/kwh)	250
Scheduled maintenance (empty 10,000 gallon tank every five years, $.04/gal)	80
TOTAL	$430

UNIT COSTS OF RDE SYSTEM

Assuming a 100 percent mortgage for 30 years at 10-1/2 percent interest, the smallest RDE system would generate annual principal and interest payments of $2,400. Including O&M costs, this represents a cost of 3.4 cents per gallon, exclusive of any homeowner's tax considerations (FIT deduction and property tax). The smallest RDE system with plastic disks and the conceivably minimal support design would cost about 2.5 cents per gallon assuming evaporation rate is unaffected by the metal supports.

SECTION 8

REFINEMENT OF MARKET ESTIMATES

COST COMPARISON OF ALTERNATIVE SYSTEMS

Table 14 lists the costs of various on-lot treatment/disposal systems. These costs are based on recent EPA publicataions [8,9] updated to 1979 conditions.

The RDE system is many times more costly than the alternative systems presented in Table 14. These alternatives represent discharging systems, and it is obvious that for any soil condition suitable for total discharging systems, the RDE device cannot compete on a cost basis. This holds true even if a minimal design, plastic disk unit were feasible.

TABLE 14. COST OF ALTERNATIVE ON-LOT TREATMENT/DISPOSAL SYSTEMS

System	Approximate 1979 Costs	
	Construction $	O&M ($/yr)
Treatment:		
Septic Tank	400	15
Aerobic Tank	2,100	200
Disposal:		
Soil Absorption System	1,500	-
Sand Mound	4,000	-
Intermittent Sand Filter	2,000	100

WATER CONSERVATION MEASURES

A number of studies[7,10] dealing with water conservation have identified measures for reducing water used by various residential activities. These studies indicate that the extensive use of water conservation measures, including drastic measures such as dry toilets, possibly could reduce the design flow by no more than 50 percent. Even if this reduces RDE system costs by the same amount, atlernative systems capable of discharging the original design flow will still be less costly.

RESTRICTED DISCHARGE SITUATIONS

The RDE system is a non-discharging system. Therefore, it has applications to situations which are inappropriate for discharging systems.

There are a number of potential development projects which cannot be realized because centralized sewer service is unavailable and site conditions prohibit full discharge of the effluent from intended uses. For many such cases involving commercial development, the cost of sewage disposal (even at prices higher than the RDE system) would represent a small part of potential cash flow.

Typically, holding tanks and periodic hauling are used for such situations. However, some states prohibit such methods, and for some situations long hauling distances result in substantial costs.

For commercial establishments, the situation has sometimes been resolved by combinations of wastewater segregating and recycling. Such recycling systems are expensive. A review of cursory cost data provided by a manufacturer indicates that recycling systems cost as much as $0.10 per gallon for an investment with 80 percent financing and 11 percent interest over ten years. A comparable RDE system, for favorable climatic conditions, would cost about $0.05 per gallon. A plastic disk unit could cost less than $0.04 per gallon.

An RDE system represents a "consumptive use" of water. For arid and semi-arid regions, recycling may be more economical overall when considering premium costs of replacement water. Furthermore, this "consumptive use" nature conflicts with water reuse programs and could lead to governmental prohibition of its application in certain localities.

OVERVIEW OF MARKET ESTIMATES

The primary objective of this marketing study is to determine the potential of RDE systems as a non-discharging alternative for unclustered, single family homes. Based on the cost data developed, it is apparent that the potential market for such an application is insignificant. The market is essentially limited to second home applications (with occupancy guaranteed only during summer months) or for very expensive homes on lots unsuitable for discharge of total wastewater flow and the use of holding tanks/periodic hauling is not acceptable. Besides costs, climate requirements would further limit the market to certain parts of the nation.

The system probably has more potential application in the commercial market. Certain commercial ventures would find the non-discharging aspects of the RDE system attractive for implementing development blocked by the unavailability of sewer service. The high cash flow, low sewage flow commercial establishments such as convenience food stores and quick food restaurants would represent the more likely uses of such systems.

The estimated potential market for RDE units of 1,000 units per year is certainly overstated when considering costs. Manufacturers would likely find it very difficult to generate sales of 100 units per year.

PROS AND CONS OF DEMONSTRATION PROJECT

Without a demonstration project, too many factors remain unresolved to prompt interest in RDE applications. Yet, the insignificant size of the potential market makes manufacturers reluctant to demonstrate the technology with their own resources. This suggests that without an EPA-funded demonstration project, RDE technology will not be developed and commercialized.

Even with a successful demonstration project, the potential market will remain insignificant in volume and limited in geographic coverage. Thus, a demonstration project is not recommended. Before making a definitive decision regarding a demonstration project, the EPA should communicate the results of this study with manufacturers of similar equipment and system offerings.

If the EPA deems a demonstration project is warranted based on other considerations, the demonstration should feature water conservation. Prior to the demonstration, a study should be made to determine the feasibility of using plastic disks.

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